CLAIMS

What is claimed is:

1. A magnetic coil and pole assembly for controlling motion of a mechanically unattached probe, the assembly comprising:

(a) a first magnetic pole carrier including a light transmissive substrate and a plurality of first magnetic pole pieces located on the substrate for applying force to a mechanically unattached magnetic probe;

(b) a magnetic drive core being magnetically coupled to the magnetic pole pieces for providing a return path for magnetic flux between the magnetic pole pieces; and

(c) a plurality of magnetic coils being wound around the magnetic drive core for conducting current and applying magnetic force to the probe through the pole pieces.

2. The assembly of claim 1 where the light transmissive substrate of the first magnetic pole carrier comprises a glass material.

3. The assembly of claim 1 wherein the pole pieces comprise thin film materials patterned on the light transmissive substrate utilizing semiconductor manufacturing techniques.

4. The assembly of claim 1 wherein the first magnetic pole pieces comprise foil materials cut from foil sheets and attached to the substrate.

5. The assembly of claim 1 wherein the first magnetic pole pieces comprise three pole pieces located in a first plane and wherein the

assembly further comprises a second pole carrier, the second pole carrier including a light transmissive substrate and a plurality of second magnetic pole pieces located on the substrate, the second magnetic pole pieces being located in a second plane parallel to the first plane.

6. The assembly of claim 5 wherein the first magnetic pole pieces include first pole tips forming vertices of a first equilateral triangle located in the first plane and the second magnetic pole pieces include pole tips forming vertices of a second equilateral triangle located in the second plane.

7. The assembly of claim 6 wherein the first equilateral triangle is rotated with respect to the second equilateral triangle by an angle of 60°.

8. The assembly of claim 1 wherein the first magnetic pole pieces include a first magnetic pole piece and a second magnetic pole piece.

9. The assembly of claim 8 wherein the first and second magnetic pole pieces each have a peaked configuration.

10. The assembly of claim 1 wherein the magnetic drive core comprises a ring structure including a plurality of tabs, wherein the magnetic coils are wound around the tabs.

11. The assembly of claim 10 wherein each tab includes an upper surface that forms a pole face, wherein each pole face is located proximally to one of the first magnetic pole pieces for applying magnetic force to the probe through the pole piece.

12. The assembly of claim 11 wherein the cross sectional area formed by the intersection of a pole face and a pole piece is greater than a distance between the pole face and the pole piece.

13. The assembly of claim 10 wherein the magnetic coils form a central aperture for receiving an objective lens.

14. The assembly of claim 1 where the magnetic coils include first and second coils located on first and second sides of each pole piece, the first and second coils being wound to present like magnetic poles in the direction of each pole piece.

15. A magnetic coil and pole assembly for applying magnetic force to a mechanically unattached magnetic probe, the assembly comprising:

(a) a first magnetic pole plate including a first light transmissive substrate and a plurality of first magnetic pole pieces located thereon;

(b) a second magnetic pole plate including a second light transmissive substrate and a plurality of second magnetic pole pieces located thereon; and

(c) a magnetic drive assembly magnetically coupled to the first and second pole pieces for applying magnetic force to a mechanically unattached magnetic probe via the pole pieces.

16. The assembly of claim 15 wherein the first and second light transmissive substrates each comprise a glass material.

17. The assembly of claim 15 wherein the first and second magnetic pole pieces comprise thin film materials manufactured using a semiconductor manufacturing technique.

18. The assembly of claim 15 wherein the first and second magnetic pole pieces comprise foil materials.

19. The assembly of claim 15 wherein the first magnetic pole pieces are located in a first plane and the second magnetic pole pieces are located in a second plane parallel to the first plane.

20. The assembly of claim 19 wherein the first magnetic pole pieces include pole tips that form vertices of a first equilateral triangle located in the first plane and wherein the second magnetic pole pieces include pole tips that form vertices of a second equilateral triangle located in the second plane.

21. The assembly of claim 20 wherein the first equilateral triangle is rotated an angle of 60° with respect to the second equilateral triangle.

22. The assembly of claim 15 wherein the magnetic drive assembly comprises a first magnetic drive ring core located proximally to the first magnetic pole plate and a second magnetic drive ring core located proximally to the second magnetic pole plate.

23. The assembly of claim 22 wherein the first and second magnetic drive ring cores include a plurality of tabs and a magnetic coil being wound around each of the tabs.

24. The assembly of claim 23 wherein each tab includes a first surface that forms a pole face and wherein each pole face is located proximately to one of the magnetic pole pieces.

25. The assembly of claim 15 wherein the magnetic drive assembly includes first and second magnetic coils located on opposite sides of each pole piece, the first and second coils being would so that the first and second magnetic coils present like magnetic poles in the direction of each pole piece.

26. A system for controlling motion of and optically tracking a mechanically unattached magnetic probe, the system comprising:

(a) a magnetic coil and pole assembly including at least one thin film or thin foil magnetic pole piece located on a light transmissive substrate and at least one magnetic coil being magnetically coupled to the pole piece for applying magnetic force to a mechanically unattached probe through the pole piece;

(b) imaging and tracking optics located proximally to the pole piece for imaging a sample under test and tracking motion of the probe;

(c) a position translation stage being mechanically coupled to a sample under test in which the probe resides; and

(d) a computer coupled to the magnetic coil and pole assembly, the imaging and tracking optics, and the position translation stage for receiving position information regarding the probe and the position translation stage and for producing control signals for moving at least one of the probe and the position translation

stage to maintain position of the probe within a predetermined volume.

27. The system of claim 26 wherein the magnetic coil and pole assembly includes first and second pole plates, each pole plate having a plurality of pole pieces located thereon.

28. The system of claim 27 wherein the pole pieces on the first plate are located in a first plane and the pole pieces on the second plate are located in a second plane parallel to the first plane.

29. The system of claim 28 wherein the pole pieces in the first plane include pole tips that form vertices of a equilateral triangle and wherein the pole pieces in the second plane include pole tips that form vertices of a second equilateral triangle located in the second plane.

30. The system of claim 29 wherein the first equilateral triangle is rotated at an angle of 60° with regard to the second equilateral triangle.

31. The system of claim 26 wherein the magnetic coil and pole assembly includes first and second magnetic pole pieces.

32. The system of claim 31 wherein the first and second magnetic pole pieces each have a peaked configuration.

33. The system of claim 31 wherein the computer is adapted to alternate polarities of the first and second magnetic pole pieces over time.

34. The system of claim 26 wherein the magnetic coil and pole assembly includes at least one magnetic core for providing a low reluctance path for magnetic flux.

35. The system of claim 34 wherein the magnetic core comprises a ring structure having a plurality of tabs located thereon and a plurality of magnetic coils being wound around the tabs.

36. The system of claim 26 wherein the imaging and tracking optics include a first objective lens located on a first side of the magnetic coil and pole assembly and a second objective lens located on a second side of the magnetic coil and pole assembly.

37. The system of claim 36 wherein at least one of the first and second objective lenses has a numerical aperture of at least one.

38. The system of claim 26 wherein the computer is adapted to simultaneously track and control the motion of the probe in three dimensions.

39. The system of claim 26 wherein the predetermined volume comprises a volume in which the imaging and tracking optics can track position of the probe.

40. The system of claim 26 wherein the computer is adapted to provide a desired position control signal to the stage to cause the sample under test to move in a desired position profile and wherein the computer is adapted to provide a probe position control signal to the magnetic coil and pole assembly for moving the probe according to a trajectory opposite that caused by moving the sample under test according to the desired position profile, thereby maintaining the probe within the predetermined volume.

41. The system of claim 26 wherein the computer is adapted to provide a desired force control signal to the magnetic coil and pole assembly for applying a desired magnetic force profile to the probe and wherein the computer is adapted to provide a position control signal to the stage for causing the sample under test to move in a trajectory opposite the trajectory of the probe during application of the magnetic force profile, thereby maintaining the probe within the predetermined volume.

42. The system of claim 26 wherein the computer is adapted to provide a desired velocity control signal to the stage for causing the sample under test to move according to a desired velocity profile and wherein the computer is adapted to provide a probe velocity control signal to the magnetic coil and pole assembly for causing the probe to move in a trajectory opposite the trajectory caused by application of the desired velocity profile, thereby maintaining the probe within the predetermined volume.

43. A method for moving and simultaneously tracking a mechanically unattached probe, the method comprising:

(a) placing a mechanically unattached magnetic probe in a sample under test;

(b) selectively magnetizing a thin film or thin foil magnetic pole piece located proximally to the magnetic probe to effect motion of the probe;

(c) while performing step (b), tracking position of the probe;

(d) tracking position of a stage on which the sample under test is located; and

(e) maintaining the position of the probe within a predetermined volume by moving at least one of the probe and the stage.

44. The method of claim 43 wherein placing a mechanically unattached probe in a sample under test includes placing a mechanically attached magnetic probe in a biological sample under test.

45. The method of claim 43 wherein selectively magnetizing a thin film or thin foil pole piece includes energizing first and second magnetic coils located on opposite sides of a first pole piece such that the like magnetic poles of the first and second coils face the first pole piece.

46. The method of claim 43 wherein selectively magnetizing a thin film or thin foil pole piece includes magnetizing at least one pole piece to create a magnetic field and gradient in the sample under test and thereby effect motion of the probe.

47. The method of claim 43 wherein tracking the probe includes tracking the probe using an objective lens having a numerical aperture of at least one.

48. The method of claim 43 wherein maintaining position of the probe includes moving the sample under test to follow a desired position profile and magnetizing the pole piece to cause the probe to follow a trajectory opposite that caused by moving the sample according to the desired position profile.

49. The method of claim 43 wherein maintaining the position of the probe includes applying a desired magnetic force profile to the probe though the pole piece and moving the sample under test to maintain the position of the probe within the predetermined volume during application of the desired magnetic force profile.

50. The method of claim 43 wherein maintaining the position of the probe includes moving the sample under test according to a desired velocity profile and magnetizing the pole piece to move the probe in a trajectory opposite that caused by moving the sample under test according to the desired velocity profile.

51. The method of claim 43 wherein the predetermined volume comprises a volume in which the position of the probe can be tracked by tracking optics.